18EED32

Hall Ticket Number:

IV/IV B.Tech (Regular/Supplementary) DEGREE EXAMINATION

November,2022 | **Electrical & Electronics Engineering**

Seventh Semester | **Electrical & Hybrid Vehicles**

Time: Three Hours | **Maximum:** 50 Marks

Answer Question No.1 compulsorily. (10X1 = 10 Marks)

Answer ONE question from each unit. (4X10=40 Marks)

1.	a)	List out any two vehicle performance parameters.	CO1	L1
	b)	Draw the ideal performance characteristics of vehicle.	CO1	L3
	c)	What is the functionality of onboard charger?	CO1	L1
	d)	Explain the power flow control in electric drive-train?	CO2	L2
	e)	What is the difference between PHEV and HEV?	CO2	L1
	f)	What is hybrid traction?	CO2	L1
	g)	What is drive system efficiency?	CO2	L1
	h)	Classify different types of Induction motor?	CO3	L2
	i)	Which energy storage system is having highest energy density among available batteries.	CO3	L1
	j)	Compare Battery based energy storage vs Super Capacitor based energy storage.	CO3	L2

Unit -I

2.	Explain the impact of modern Electric Vehicles Over Conventional Vehicles.	CO1, L2	10M
	(OR)		
3.	Discuss the mathematical modeling to describe the performance of the vehicle.	CO1, L2	10M

Unit -II

4.	Explain in detail about power flow control in hybrid drive-train topologies.	CO2, L2	10M
	(OR)		
5.	Analysis the fuel efficiency of electric drive-train topologies.	CO2, L4	10M

Unit -III

6.	Explain in detail about various electric components used in electric vehicles.	CO3, L2	10M
	(OR)		
7.	Discuss about the configuration and control of DC Motor drives.	CO3, L2	10M

Unit -IV

8.	Explain in detail about classification of different energy management strategies.	CO4, L2	10M
	(OR)		
9.	Discuss about Battery based energy storage with its analysis.	CO4, L2	10M

1a) vehicle performance parameters.

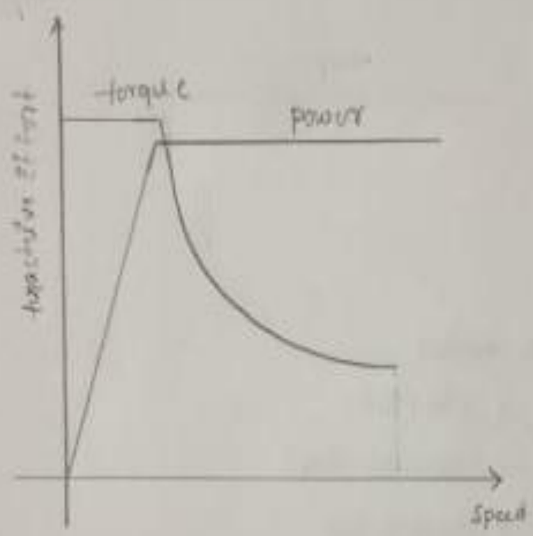
golling resistance force

Aerodynamic tyactive force

Hill climbing force

acceleration force

1b) Ideal performance characteristics of vehicles.



1c) functionality of on-board charger

An on-board charger is used in EV and HEV to charge the traction battery by converting the AC input form the grid to a DC input which charges the battery

1d) power flow control in Electric drive

Source → Power Modulators → Motors → load

load ↓ Sensing unit

Sensing unit → control unit

control unit → Power Modulators

Input command → control unit

1e) difference b/w PEHV & HEV

The primary difference b/w an HEV and PHEV is the addition of a charging port into the PHEV. That's why we are all called plug-in electric vehicle. The travel distance in PEHV is less than HEV

1f) Hybrid traction.

Hybrid traction combines multiple power sources and so can potentially cover many powertrain options to achieve the desired benefits. The addition of alternative power source whilst adding complexity can provides many co-benefits along with decarbonisation of the railway station.

1g) Drive system Efficiency

1h) different types of induction Motor

- induction Motor
  - 1-φ
    - split phase
    - capacitor start
    - shaded pole
  - 3-φ
    - squirrel cage
    - slip ring

1i) Lithium-ion battery with the highest energy density is the Lithium cobalt-oxide battery.

1j)

Ultra/super Capacitors	Batteries
• Super capacitors have higher power density, quick charge/discharge rate and longer life cycle	• Batteries have a low power density and the charge/discharge process is relatively slower
• Stored energy is in Electric field	• The stored energy is in chemical energy

2. Explain the impact of modern Electric Vehicles Over Conventional Vehicles.

Electric vehicle: Any vehicle propelled by an electric drivetrain draining taking power from a rechargeable battery or from a portable, refillable, electrical energy source (like fuel cell, solar panels, etc.), which is manufactured for use on public roads Definition: Electric Vehicle electric drivetrain rechargeable battery portable, refillable, electrical energy source public road.

HEV Advantages Over Conventional Engines

- Regenerative Braking
- Reduction in engine and vehicle weight
- Fuel efficiency is increased
- Emissions are decreased
- Cut emissions of global warming pollutants by 1/3 or 1/2
- Reduce the dependency on fossil fuels
- Some states offer incentives with owning an HEV
- 2 times more efficient than conventional engines

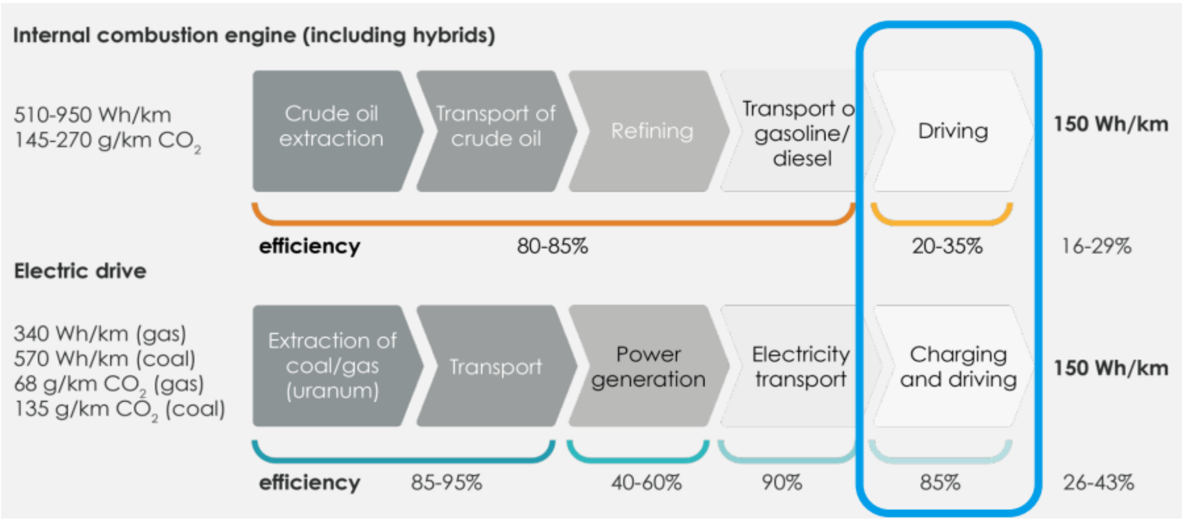
Benefits of EV:

Sustainability:

- EVs have no tail-pipe emission
- Reduced air pollution in cities due to CO2, Sox, NOx, particulate matter

Efficiency:

- Well to wheel efficiency is higher.



Health and environmentally friendly

Convenience:

- Quieter
- No gear changes
- Low components & maintenance
- Large storage place
- Self-driving
- Charging at home

Lower total cost of ownership:

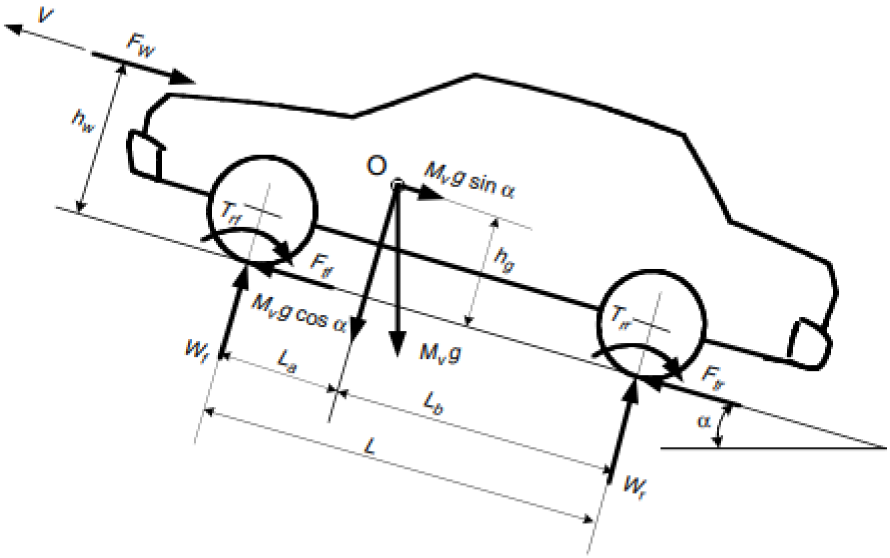
- Higher purchase price, BUT
- Lower maintenance costs
- Lower taxes
- Cheaper fuel (electricity)
- Govt. subsidy

3. **Discuss the mathematical modeling to describe the performance of the vehicle.**

The tractive effort, Ft , in the contact area between tires of the driven wheels and the road surface propels the vehicle forward. It is produced by the power plant torque and is transferred through transmission and final drive to the drive wheels. While the vehicle is moving, there is resistance that tries to stop its movement. The resistance usually includes tire rolling resistance, aerodynamic drag, and uphill resistance.
According to Newton's second law, vehicle acceleration can be written as

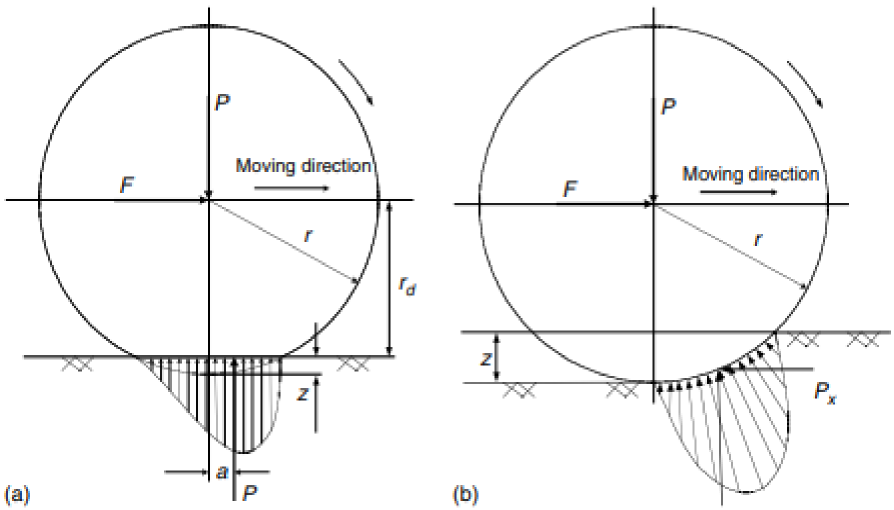
$$\frac{dV}{dt}=\frac{\Sigma F_t-\Sigma F_{tr}}{\delta M_v},$$

where V is vehicle speed, ΣFt is the total tractive effort of the vehicle, ΣFtr is the total resistance, Mv is the total mass of the vehicle, and δ is the mass factor, which is an effect of rotating components in the power train.



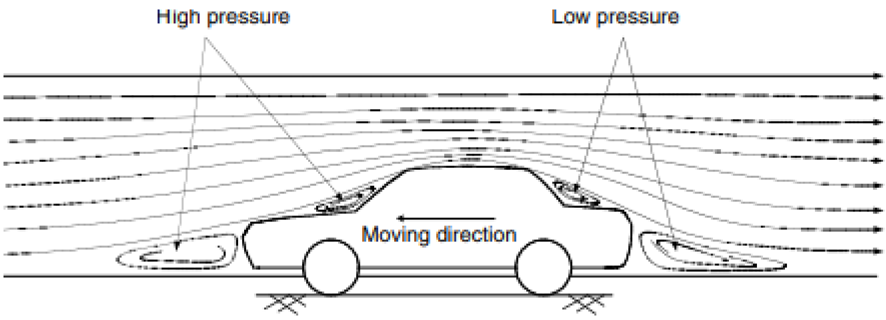
Rolling resistance:

The rolling resistance of tires on hard surfaces is primarily caused by hysteresis in the tire materials. This is due to the deflection of the carcass while the tire is rolling. The hysteresis causes an asymmetric distribution of ground reaction forces. The pressure in the leading half of the contact area is larger than that in the trailing half, as shown in Figure (a). This phenomenon results in the ground reaction force shifting forward. This forwardly shifted ground reaction force, with the normal load acting on the wheel center, creates a moment, that opposes the rolling of the wheel. On soft surfaces, the rolling resistance is primarily caused by deformation of the ground surface as shown in Figure (b). The ground reaction force almost completely shifts to the leading half.



Aero dynamic drag:

A vehicle traveling at a particular speed in air encounters a force resisting its motion. This force is referred to as an aerodynamic drag. It mainly results from two components: shape drag and skin friction.
Shape drag: The forward motion of the vehicle pushes the air in front of it. However, the air cannot instantaneously move out of the way and its pressure is thus increased, resulting in high air pressure. In addition, the air behind the vehicle cannot instantaneously fill the space left by the forward motion of the vehicle. This creates a zone of low air pressure. The motion has therefore created two zones of pressure that oppose the motion of a vehicle by pushing it forward (high pressure in front) and pulling it backward (low pressure in the back) as shown in below Figure. The resulting force on the vehicle is the shape drag.



Skin friction: Air close to the skin of the vehicle moves almost at the speed of the vehicle while air far from the vehicle remains still. In between, air molecules move at a wide range of speeds. The difference in speed between two air molecules produces friction that results in the second component of aerodynamic drag. Aerodynamic drag is a function of vehicle speed V, vehicle frontal area Af , shape of the vehicle, and air density ρ. Aerodynamic drag is expressed as

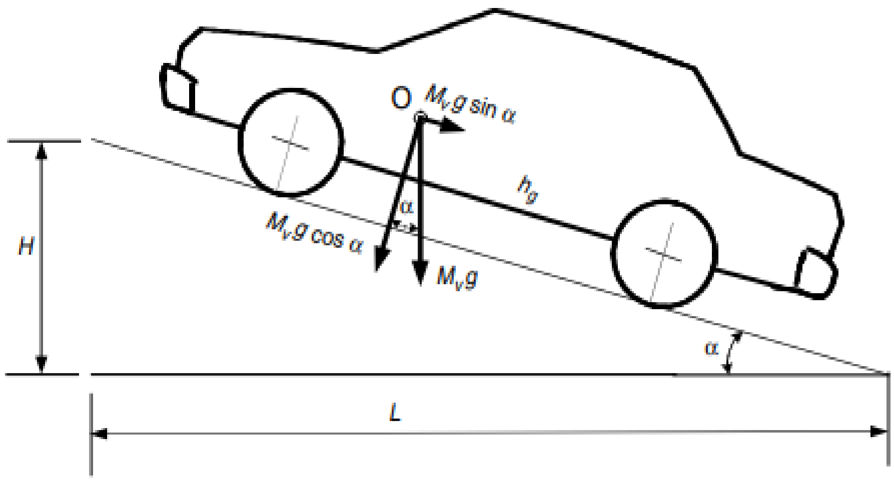
$$F_w = \frac{1}{2}\rho A_f C_D (V+V_w)^2,$$

where CD is the aerodynamic drag coefficient that characterizes the shape of the vehicle and Vw is the component of wind speed on the vehicle's moving direction, which has a positive sign when this component is opposite to the vehicle speed and a negative sign when it is in the same direction as vehicle speed.

Grading Resistance:

When a vehicle goes up or down a slope, its weight produces a component, which is always directed to the downward direction, as shown in below Figure. This component either opposes the forward motion (grade climbing) or helps the forward motion (grade descending). In vehicle performance analysis, only uphill operation is considered. This grading force is usually called grading resistance. The grading resistance from below Figure, can be expressed as

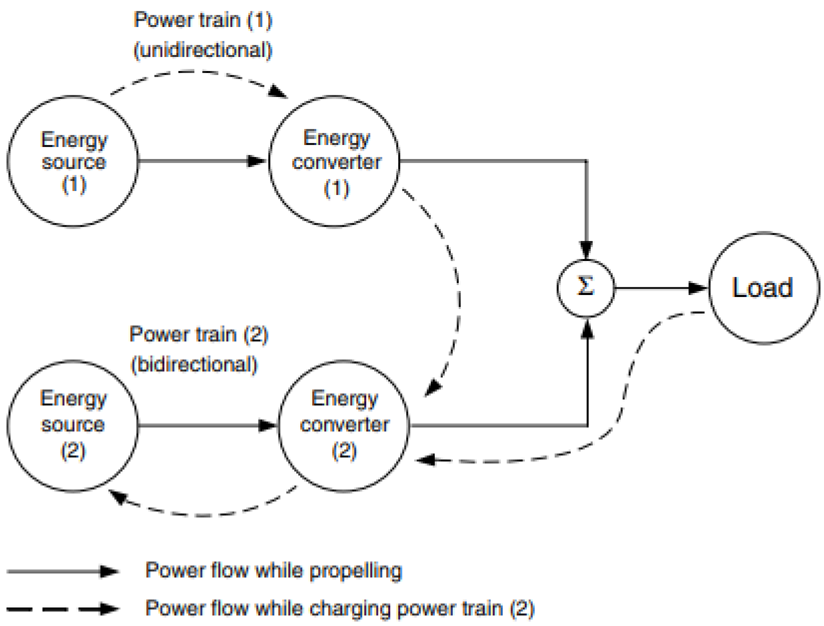
$$F_g = M_v g \sin\alpha.$$



4. **Explain in detail about power flow control in hybrid drive-train topologies**.

Basically, any vehicle power train is required to
(1) develop sufficient power to meet the demands of vehicle performance,
(2) carry sufficient energy on board to support vehicle driving in the given range,
(3) demonstrate high efficiency
(4) emit few environmental pollutants.

Broadly, a vehicle may have more than one energy source and energy converter (power source), such as a gasoline (or diesel) heat engine system, hydrogen–fuel cell–electric motor system, chemical battery–electric motor system, etc. A vehicle that has two or more energy sources and energy converters is called a hybrid vehicle. A hybrid vehicle with an electrical power train (energy source energy converters) is called an HEV. A hybrid vehicle drive train usually consists of no more than two power trains. More than two power train configurations will complicate the system. For recapturing part of the braking energy8 that is dissipated in the form of heat in conventional ICE vehicles, a hybrid drive train usually has a bidirectional energy source and converter. The other one is either bidirectional or unidirectional. Below Figure shows the concept of a hybrid drive train and the possible different power flow routes.



Hybrid drive trains supply the required power by an adapted power train. There are many available patterns of combining the power flows to meet load requirements as described below:
1. Power train 1 alone delivers power to the load.
2. Power train 2 alone delivers power to the load.
3. Both power trains 1 and 2 deliver power to load at the same time.
4. Power train 2 obtains power from load (regenerative braking).
5. Power train 2 obtains power from power train 1.
6. Power train 2 obtains power from power train 1 and loads at the same time.
7. Power train 1 delivers power to load and to power train 2 at the same time.
8. Power train 1 delivers power to power train 2, and power train 2 delivers power to load.
9. Power train 1 delivers power to load, and load delivers power to power train 2.

In the case of hybridization with a liquid fuel-IC engine (power train 1) and a battery-electric machine (power train 2), pattern (1) is the engine-alone propelling mode. This may be used when the batteries are almost completely depleted and the engine has no remaining power to charge the batteries, or when the batteries have been fully charged and the engine is able to supply sufficient power to meet the power demands of the vehicle. Pattern (2) is the pure electric propelling mode, in which the engine is shut off. This pattern may be used in situations where the engine cannot operate effectively, such as very low speed, or in areas where emissions are strictly prohibited. Pattern (3) is the hybrid traction mode and may be used when a large amount of power is needed, such as during sharp acceleration or steep hill climbing. Pattern (4) is the regenerative braking mode, by which the kinetic or potential energy of the vehicle is recovered through the electric motor functioning as a generator. The recovered energy is stored in the batteries and reused later. Pattern (5) is the mode in which the engine charges the batteries while the vehicle is at a standstill, coasting, or descending a slight grade, in which no power goes into or comes from the load. Pattern (6) is the mode in which both regenerative braking and the IC engine charge the batteries simultaneously. Pattern (7) is the mode in which the engine propels the vehicle and charges the batteries simultaneously. Pattern (8) is the mode in which the engine charges the batteries, and the batteries supply power to the load. Pattern (9) is the mode in which the power flows into the batteries from the heat engine through the vehicle mass. The typical configuration of this mode is two power trains separately mounted on the front and the rear axle of the vehicle.

6. Explain in detail about various electric components used in electric vehicles.

Electric vehicle:

A vehicle that has two or more energy conversion technologies combined with one or more energy storage units.

HEV Components

- Electric Motors/Controllers
- Electric Energy Storage systems
- Hybrid power units
- Transmission
-

1. **Electric Motors/Controllers components:**
    - An Armature or Rotor
    - A Commutator
    - Brushes
    - An Axle
    - Field Magnet
    - DC Power Supply

Electric Motor/Controllers

- Advanced electronics allows the motor to act as a generator
- Draws energy to accelerate and regenerates the battery when slowing down
- Motor uses magnets and magnetism to create motion

2. **Electric Energy Storage Systems**
    - Batteries: Lithium Ion and Nickel-metal hydride batteries
    - Ultracapacitors
    - Flywheel

Desirable attributes:

High-peak and pulse specific power

High specific energy at pulse power

High charge to maximize regenerative braking

Long life

Challenges:

Accurate techniques to determine battery state of charge

Develop abuse-tolerant batteries

Recyclability

Ultra-capacitor: Store energy as an electric charge in a polarized liquid layer between an ionically electrolyte and conducting electrode and primarily used for acceleration, climbing hills and regenerative braking.

Fly wheel: 1) Store kinetic energy within a rapidly spinning wheel,2) Complex, heavy, and large 3) contains no acid or hazardous material 4) Not affected by temperature 5) Delivers a smooth flow of power.

3.Hybrid power units:

- Compression Ignition Direct Injection Engines (CIDI)
- spark Ignition Engines
- Gas Turbines
- Fuel Cells

CIDI: Most promising power unit,

Achieves combustion through compressions without the use of a spark plug.

High pressure injection of the fuel into the combustion chamber.

Throttle and heat losses travels into the combustion chamber increasing thermal efficiency.

Spark ignition: Runs on an Otto cycle

Uses a homogeneous air-fuel mixture before entering the combustion chamber.

When the combustion chamber is compressed, the spark plug is ignited.

Controlled by limiting the amount of air allowed into the engine.

Gas turbines: Runs on a Brayton cycle

A compressor raises the pressure and temperature of the inlet air.

Air is moved to the burner and fuel is injected and combusted to raise the air temperature.

Power is produced when the heated pressure mixture is expanded and cooled through the turbine.

Fuel cells: Generate electricity through an electrochemical reaction combining hydrogen with ambient air.

Pure hydrogen or any fossil fuel produced is used as hydrogen-rich gas.

Water vapor is emitted.

4.Transmission:

Continuous Variable Transmission (CVT)

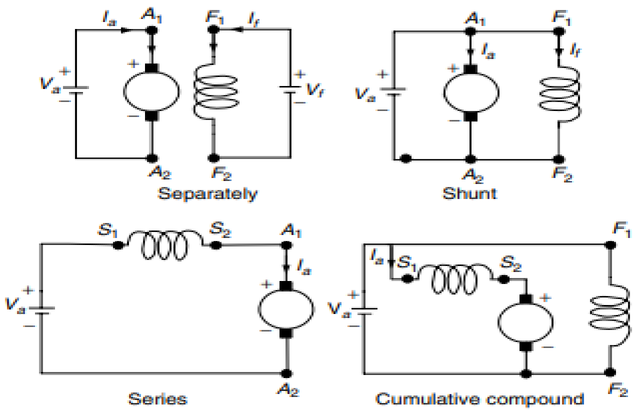
Automated shifted transmission

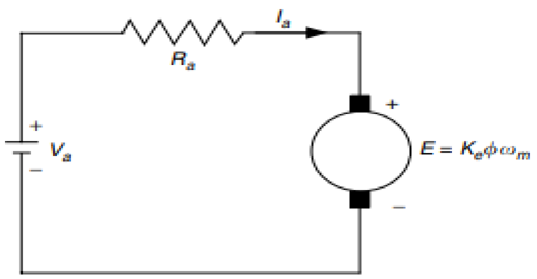
Manual transmission

Traditional automatic transmission with torque converter

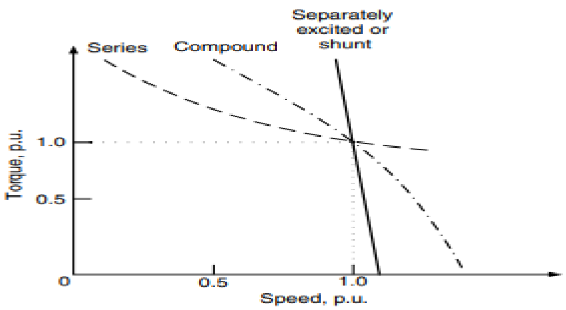
7. Discuss about the configuration and control of DC Motor drives.

DC motor drives have been widely used in applications requiring adjustable speed, good speed regulation, and frequent starting, braking, and reversing. Various DC motor drives have been widely applied to different electric traction applications because of their technological maturity and control simplicity.



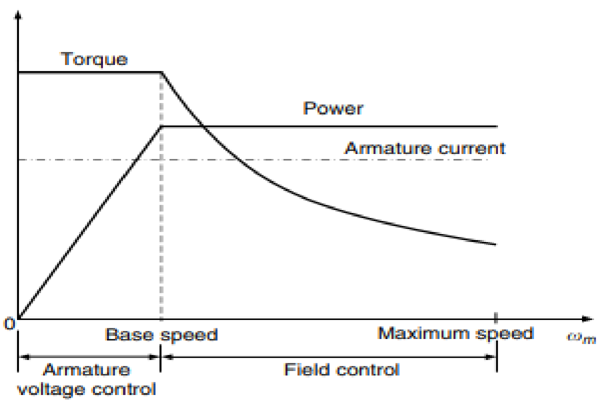


A speed–torque characteristic of a series DC motor is shown in Figure 6.6. In the case of series, any increase in torque is accompanied by an increase in the armature current and, therefore, an increase in magnetic flux. Because flux increases with the torque, the speed drops to maintain a balance between the induced voltage and the supply voltage. The characteristic, therefore, shows a dramatic drop. A motor of standard design works at the knee point of the magnetization curve at the rated torque. At heavy torque (large current) overload, the magnetic circuit saturates and the speed–torque curve approaches a straight line.



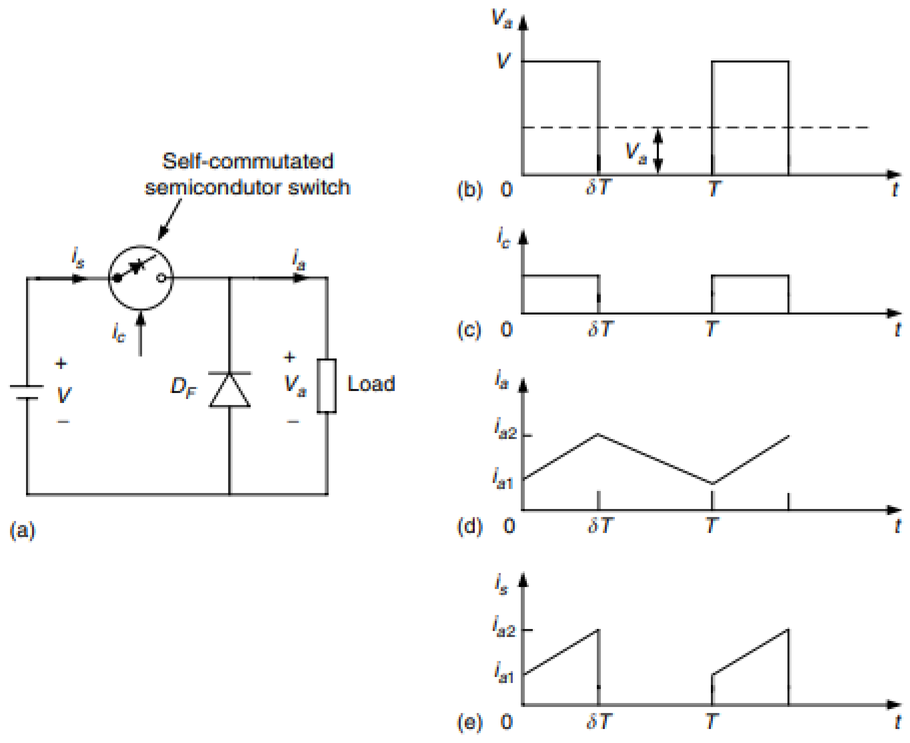
Combined Armature Voltage and Field Control:

The independence of armature voltage and field provides more flexible control of the speed and torque than other types of DC motors. In EV and HEV applications, the most desirable speed–torque characteristic is to have a constant torque below a certain speed (base speed), with the torque dropping parabolically with the increase of speed (constant power) in the range above the base speed.



Chopper Control of DC Motors:

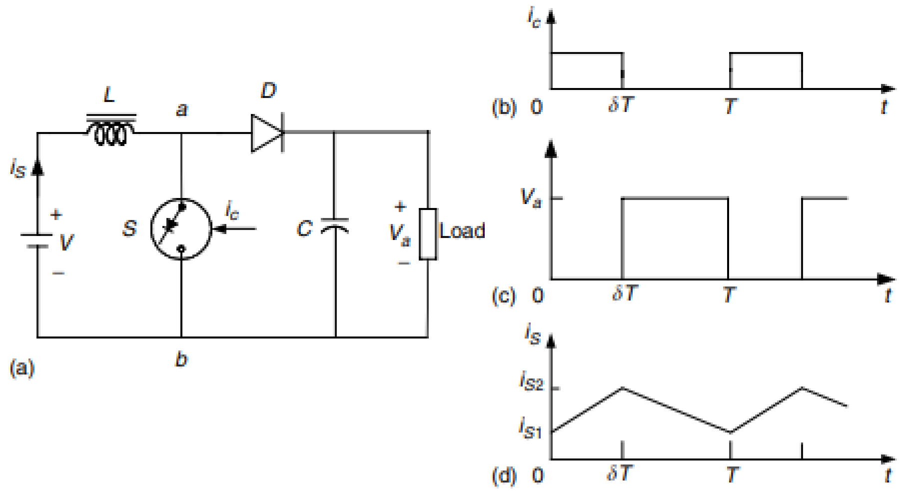
Choppers are used for the control of DC motors because of several advantages such as high efficiency, flexibility in control, light weight, small size, quick response, and regeneration down to very low speeds. Presently, the separately excited DC motors are usually used in traction, due to the control flexibility of armature voltage and field.



Step down chopper

The switch S can be controlled in various ways for varying the duty ratio δ. The control technologies can be divided into the following categories:

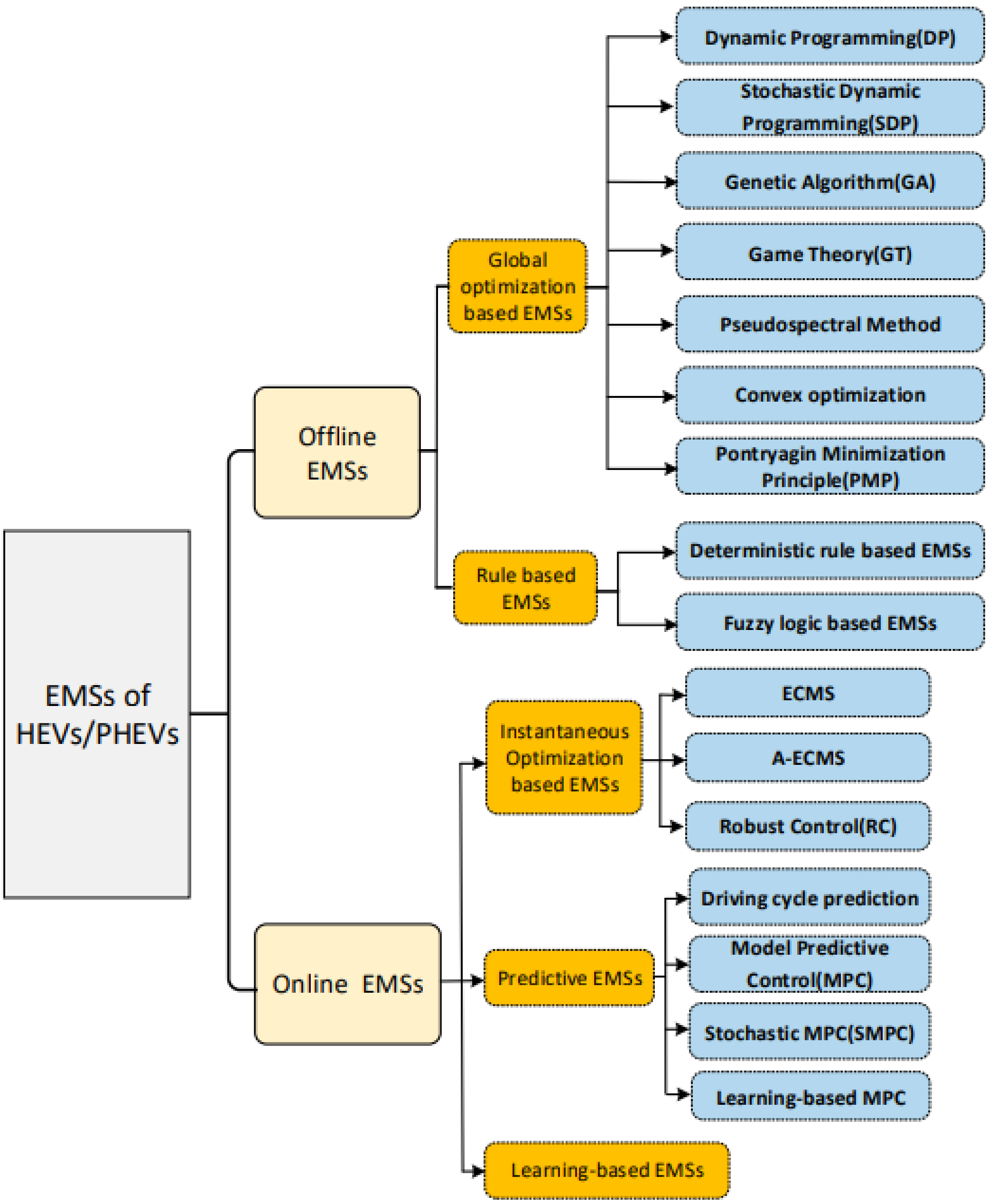
1. Time ratio control (TRC). 2. Current limit control (CLC).



Step up chopper

8. Explain in detail about classification of different energy management strategies.

Classification scheme of EMSs for all kinds of Hybrid Electric Vehicles via two main headlines: (1) offline EMSs are categorized according to the information level of the driving conditions utilized, including global optimization based-EMSs and rule-based EMSs; and (2) online EMSs are represented as instantaneous optimization-based EMSs, predictive EMSs, and learning-based EMSs. The classification of the EMSs is illustrated in Figure 4. It is noted that a flexible EMS can include a mixture of various techniques (offline and online) to form an integrated EMS for improving the fuel economy and performance. Thus, in this paper, these combinations with other techniques may be included while providing a particular EMS classification. For offline EMSs, two categorizations are illustrated: the global optimization-based and rule-based EMSs. The main goal of global optimization-based EMSs is to achieve a global optimal power split under a given driving cycle and provide modified online EMSs. They are not directly applicable in real-time control due to their computational complexity and the requirement of a priori knowledge of the entire driving cycle. However, it can be used as a benchmark to adjust the control parameters. Typical methods, such as dynamic programming, can implement global optimization over given driving cycles, but it cannot be directly employed in a real vehicle. Therefore, this method can be used to evaluate the performance of other optimization methods to extract the control rules. Rulebased EMSs are considered as an offline method since the rules are derived from pre-production tests. Rule-based EMSs are based on pre-defining a series of control rules to determine the power split while it cannot achieve optimal allocation of power as compared to offline globally optimized energy management. Online EMSs, however, are based on local optimization and causal with the potential of being applied in real-time control. Among these strategies, Instantaneous optimization EMSs can minimize the instantaneous fuel consumption at each instant without a priori knowledge of the entire driving cycle and only obtain local optimal results. The instantaneous optimizationbased EMSs are 1) the equivalent consumption minimization strategy (ECMS); 2) adaptive-ECMS (AECMS); and 3) robust control (RC). As a fundamental method, ECMS can be used for real-time implementation due to its adjustability.



Global Optimization-Based EMSs: These types of methods are non-causal and seek global optimal solutions since they need a prior knowledge of the typical driving cycle. Because of the non-casual solution, they cannot directly be employed in real-time problems; however, non-causal optimal solutions can be obtained offline under a given driving cycle, which can provide a benchmark for other algorithms or modified online EMSs. Thus, as a benchmark, these methods can be adopted to obtain globally optimal results under a specific driving cycle. The commonly methods, such as dynamic programming (DP), stochastic dynamic programming (SDP), genetic algorithm (GA), game theory (GT), robust control (RC), pseudo spectral method, and convex optimization, are illustrated and compared in this section. To clearly illustrate the pros and cons of each approach, a comparison of different approaches is shown in Table 1. The “computational complexity” requires low computational burden to score well since this is desirable for fast operation and efficiency. The “adaptability” refers to the flexibility of the EMSs adapted in different driving cycles. It scores well when the control parameters are easy to adjust to different driving cycles for fuel economy. The SDP can provide the best adaptability in comparison with other methods. The “priori knowledge of driving cycle” denotes the amount of driving future information required for calibration and formulation. For these methods, the DP requires the most a priori knowledge of the future information of the driving cycle and obtains the best fuel economy.

Dynamic programming: It is as an offline optimization approach, can realize a global optimal solution for a given driving cycle; however, it cannot directly be used in a real vehicle EMS because it is impossible to know the future driving conditions (speed, road slope as well as traffic dynamics). DP also suffers from considerable computing time for solving the optimal problem of the backward duration of the trip from the future state to find the initial control input in a feasible region. Especially, the computation burden increases as the dimension of the system states raise. However, as a benchmark, it can be used to determine the operating conditions that yield a globally optimal fuel consumption, which is then further used to evaluate the performance of other energy management algorithms and extract some heuristic rules.

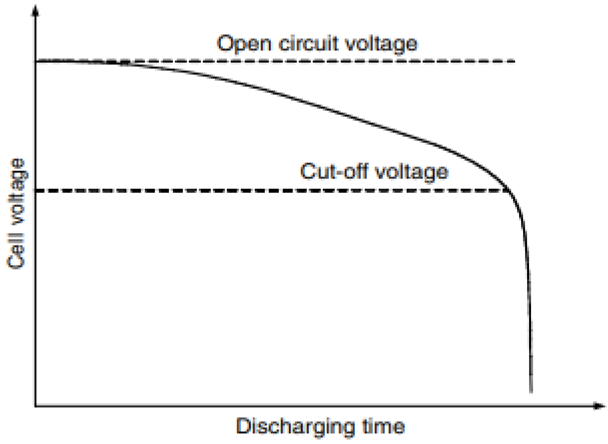
Stochastic Dynamic Programming (SDP): Although DP is regarded as a useful tool to obtain a global optimal solution, it is impossible to know exactly the whole driving cycle conditions (speed, road slope, etc.) in advance. To address this issue, stochastic dynamic programming is proposed by researchers. The basic principle of stochastic dynamic programming is that assuming that the sequence of values can be modelled using Markov chain power, the state transition matrix map of the future driver’s power demand is generated to estimate the driver’s power demand. The power sequence demand is calculated by discretizing the historical driving data at a certain step, and the determination of the current power demand is made in terms of the vehicular speed. The maximum likelihood estimation method is utilized to obtain the state transition probability from the current state to the next one by distributing the total power using discrete dynamic programming. It has been successfully applied as a promising approach for obtaining a quasi-optimal policy that is implementable on-line and in real time, since only historical driving data is needed without a priori knowledge of the driving cycle.

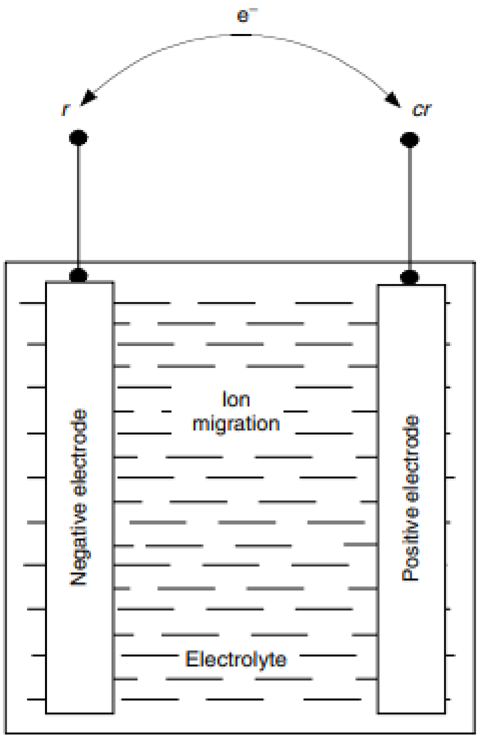
Rule-Based EMSs: Generally, rule-based EMSs can be performed by predefining the logical rules according to the HEV system characteristics and operation mode. The rules are determined based on the battery SOC, driver power demand, and vehicle velocity through an “if–then” structure. Given these rules, the power split can be performed to meet the driver power demand and maintain the SOC at a certain range. Instead of a prior knowledge of the driving cycle, this method mainly depends on logical rules and local constraints.

Online EMSs: Online EMSs are causal and local optimization-based since they generally do not require a priori knowledge of the whole driving cycle. They can be implemented in real-time with a limited computational burden by converting the global optimization problem of off-line EMSs into an instantaneous optimization problem. Due to less computational effort, on-line EMSs yields the potential of being implemented in real-time control problems. Three categories are included, namely instantaneous optimization-based EMSs, predictive EMSs, and learning-based EMSs. The instantaneous optimization-based EMSs determines the power split with optimal algorithm utilizing the current driving cycle information while the predictive EMSs mainly employ future information to optimize the power split.

9. Discuss about Battery based energy storage with its analysis.

Electrochemical batteries, more commonly referred to as “batteries,” are electrochemical devices that convert electrical energy into potential chemical energy during charging and convert chemical energy into electric energy during discharging. A “battery” is composed of several cells stacked together. A cell is an independent and complete unit that possesses all the electrochemical properties. Basically, a battery cell consists of three primary elements: two electrodes (positive and negative) immersed into an electrolyte as shown in below Figure. Battery manufacturers usually specify the battery with coulometric capacity (amp-hours), which is defined as the number of amp-hours gained when discharging the battery from a fully charged state until the terminal voltage drops to its cut-off voltage, as shown. It should be noted that the same battery usually has a different number of amp-hours at different discharging current rates.





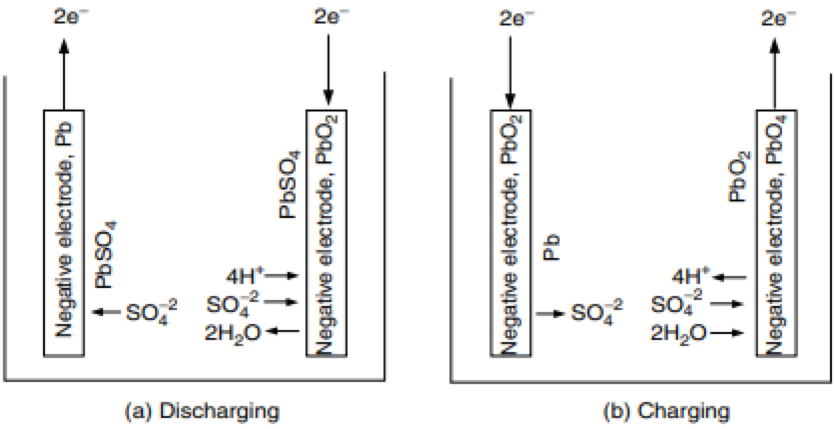
The change in SOC in a time interval, dt, with discharging or charging current i may be expressed as

$$\Delta SOC = \frac{i\,dt}{Q(i)},$$

where Q(i) is amp-hour capacity of the battery at current rate i. For discharging, i is positive, and for charging, i is negative. Thus, the SOC of the battery can be expressed as

$$SOC = SOC_0 - \int \frac{i\,dt}{Q(i)},$$

where SOC0 is the initial value of the SOC.



Lead-Acid Batteries: The lead-acid battery has been a successful commercial product for over a century and is still widely used as electrical energy storage in the automotive field and other applications. Its advantages are its low cost, mature technology, relative high-power capability, and good cycle. These advantages are attractive for its application in HEVs where high power is the first consideration. The materials involved (lead, lead oxide, sulfuric acid) are rather low in cost when compared to their more advanced counterparts. Lead-acid batteries also have several disadvantages. The energy density of lead-acid batteries is low, mostly because of the high molecular weight of lead. The temperature characteristics are poor.2 Below 10°C, its specific power and specific energy are greatly reduced. This aspect severely limits the application of lead-acid batteries for the traction of vehicles operating in cold climates.

Nickel-based Batteries: Nickel is a lighter metal than lead and has very good electrochemical properties desirable for battery applications. There are four different nickel-based battery technologies: nickel–iron, nickel–zinc, nickel–cadmium, and nickel–metal hydride.

Nickel/Iron System: - The nickel/iron system was commercialized during the early years of the 20th century. Applications included fork-lift trucks, mine locomotives, shuttle vehicles, railway locomotives, and motorized hand-trucks.1 The system comprises a nickel (III) hydroxy-oxide (NiOOH) positive electrode and a metallic iron negative electrode. The electrolyte is a concentrated solution of potassium hydroxide (typically 240 g/l) containing lithium hydroxide (50 g/l). The cell reaction is given in Table 10.1 and its nominal open-circuit voltage is 1.37 V.

Nickel/Cadmium System The nickel/cadmium system uses the same positive electrodes and electrolyte as the nickel/iron system, in combination with metallic cadmium negative electrodes. The cell reaction is given in Table 10.1 and its nominal open-circuit voltage is 1.3 V. Historically, the development of the battery has coincided with that of nickel/iron and they have a similar performance.

Lithium-Based Batteries: Lithium is the lightest of all metals and presents very interesting characteristics from an electrochemical point of view. Indeed, it allows a very high thermodynamic voltage, which results in a very high specific energy and specific power. There are two major technologies of lithium-based batteries: lithium–polymer and lithium-ion. Lithium–polymer batteries use lithium metal and a transition metal intercalation oxide (MyOz) for the negative and positive electrodes, respectively. This MyOz possesses a layered structure into which lithium ions can be inserted, or from where they can be removed on discharge and charge, respectively.